(12) EUROPEAN PATENT APPLICATION

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(54) NOx release index

(57) Method of monitoring the adsorptive capacity of a NO_X adsorber of an internal combustion engine, comprising the following steps:

1) identification of O_2 moles released from the adsorber during rich pulse regeneration,
2) calculation of NO_2 moles released during rich pulse regeneration using the value from step 1 in a release model based on lambda deviation across the adsorber and the release chemistry of NO_2 from said adsorber

3) optional storage of successive results of steps 1 and 2
4) use of the results of step 2 and/or 3 to update an adaptative capacity model to control the duration of the lean phase and/or of the rich pulse.

EP 1 273 337 A1

Description

[0001] This invention relates to a method and a system for monitoring the adsorptive capacity of NO_x adsorber devices of internal combustion engines.

[0002] NO_x adsorber devices are currently used to address one of the drawbacks of lean burn engines, namely difficulty to reduce initrogen oxides (NO_x) in a lean environment. NOx adsorber technology typically uses alkali or alkali-earth metals in order to temporarily store NO_x under lean operating conditions and to release the NO_x during periodic and relatively short rich pulses.

[0003] The mechanism for NO_x storage involves the oxidation of NO to NO_2 followed by the subsequent formation of a nitrate complex with alkaline or alkaline earth metals. Under stoichiometric or rich conditions, the nitrate complexes are thermodynamically unstable and the stored NO_x is released and catalytically reduced to nitrogen by the excess of CO, H_2, and hydrocarbon compounds in the exhaust gases.

[0004] The storage capacity of such an NO_x adsorber degrades over time due to thermal ageing, but mainly due to sulfur poisoning, with resultant increase in atmospheric pollution and fuel consumption. The same alkali and alkali-earth metals that can store NO_x under lean conditions are also excellent scavengers for SO_2 and SO_3 under these same conditions. The resulting sulfates are very stable and result in rapid deactivation of the NO_x adsorber. Unfortunately, the levels of sulfur in gasoline are usually quite high and very variable, the average being about 50 to 300 parts per million (ppm). To purge the sulfur, frequent periods of extended hot, rich operation, so called desulfation processes, may thus be required with the known effects on overall fuel consumption.

[0005] Current diagnostic methods and systems are based on semi-empirical models to estimate the actual performance of an adsorber and thus to control the duration of lean and/or rich operating conditions, to identify sulfur poisoning and to trigger a desulfation process to regenerate the adsorber. To get a sufficient level of accuracy, these models need to be carefully calibrated and are generally acceptable or valid only for steady operation or a relatively small range of operating conditions. They are therefore less appropriate for automobile engines which are operating under very fluctuating conditions of temperature, load, fuel characteristics, etc.

[0006] Accordingly, it is desirable to provide a method that allows a better NOx adsorber diagnostic indicating the actually available NO_x storage capacity at any time without the drawbacks described above.

[0007] The present invention provides in accordance to a first aspect of the present invention a method of monitoring the adsorptive capacity of a NO_x adsorber of an internal combustion engine, comprising the following steps:

1) identification of O_2 moles released from the adsorber during rich pulse regeneration,
2) calculation of NO_2 moles released during rich pulse regeneration using the value from step 1 in a release model based on lambda deviation across the adsorber and the release chemistry of NO_2 from said adsorber
3) optional storage of successive results of steps 1 and 2
4) use of the results of step 2 and/or 3 to update an adaptative capacity model to control the duration of the lean phase and/or of the rich pulse.

[0008] By estimating the quantity of NO_x stored during the previous lean period, it is possible to calculate an average storage capacity or efficiency of the NO_x adsorber in order to maximise the fuel economy and to minimise tailpipe NO_x emissions. The major advantage of the present method over the state of the art is that the model used to estimate or calculate the quantity of NO_x released by the adsorber during rich operating conditions is based on a physical model of the release chemistry, not on empirical parameters. Besides a greater accuracy, the benefits of this approach are generic formulae independent of calibration, engine conditions, regeneration air to fuel ratio, etc. The ease of calibration dramatically reduces the calibration time needed for previous methods usually prone to a large number of fluctuations. Another interesting feature of the present method is its independence of the fuel characteristics, underlining its generic character.

[0009] As mentioned above, the current abdorber materials are relatively sensitive to sulfur poisoning which degrades the storage capacity of the NO_x adsorber. When the storage capacity drops under a predetermined value, i.e. when the maximum quantity of NO_x stored during lean phase and released during rich pulse reaches an insufficient level, actions must be taken to restore at least part of the initial capacity.

[0010] Therefore the present method comprises preferably the following additional step:

5) use of the results of step 2 and/or 3 to update an adaptative capacity model to detect sulfur poisoning of the adsorber and to trigger a desulfation process.

[0011] Due to a better monitoring of the adsorber capacity, an improved sulfur contamination diagnostic can be achieved. This not only results in reduced fuel consumption, but decreases also drastically adsorber replacement costs owing to a more efficient regeneration and hence a greater durability.

[0012] Another benefit of this better NO_x adsorber capacity usage and diagnostic is a possible downsizing of the adsorber with concomitant cost and space requirement reductions.

[0013] In a preferred embodiment of the present method wherein the release model in step 2 is based on following equation:

$$ANO_{2\,released} = \left[1 - \frac{AO_{2\,released}}{FO_{2\,released}}\right]FNO_{2\,released}$$

wherein:

$ANO_{2\,released}$: actual (calculated) moles of NO_2 released from the adsorber during rich pulse regeneration

$AO_{2\,released}$: measured O_2 moles during rich pulse

$$FO_{2\,released} = \left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{rich\,pulse}\left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1\right)Airflow_{rich\,pulse}\,.dt$$

$FO_{2released}$ represents a fictive mole amount of O_2 released assuming that the lambda deviation was caused only by O_2

$$FNO_{2\,released} = \frac{4}{3}\left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{rich\,pulse}\left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1\right)\left(\frac{1}{1 + \frac{2}{3}\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}\lambda_{TLP}}\right)Airflow_{rich\,pulse}\,.dt$$

$FNO_{2released}$ represents a fictive mole amount of O_2 released assuming that the lambda deviation was caused only by NO_2

$$\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}:$$

oxygen to carbon ratio at stoichiometric operating conditions

$$\left(\frac{mole\,O_2}{mole\,air}\right)_{air}:$$

molar oxygen to air ratio in ambient air

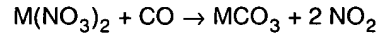$$\lambda_{EO} = \frac{\left(\frac{mole\,O_{2\,EO}}{mole\,C_{EO}}\right)}{\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}}:$$

lambda value upstream of the adsorber (EO, engine out)

$$\lambda_{TLP} = \frac{\left(\dfrac{mole\, O_{2TLP}}{mole\, C_{TLP}} \right)}{\left(\dfrac{mole\, O_2}{mole\, C} \right)_{stoich}} :$$

lambda value downstream of the adsorber (TLP, tailpipe)

$Airflow_{rich\,pulse}$: airflow during rich pulse.

[0014] As stated above, the present method is base on the lambda variation across the adsorber and the release chemistry of the NO_x from said adsorber. The following description will try to support and to illustrate the above formulae.
[0015] The reaction which summarizes the NO_x release from a NO_x adsorber using a current technology could be represented as follows:

$$M(NO_3)_2 + CO \rightarrow MCO_3 + 2\, NO_2$$

- Oxygen balance in the exhaust gas:

  Net O_2 moles transferred to the gas = (2 - ½) O_2 moles = 1.5 O_2 moles
  For each mole NO_2 released, 0.75 mole O_2 are added to the exhaust gases.

- Carbon balance in the exhaust gas:

  Net C moles transferred to the gas = -1 C mole
  Thus, for each mole NO_2 released, 0.5 mole C are subtracted to the exhaust gases.

[0016] To know the impact of NO_x release on lambda deviation across NO_x adsorber during rich regeneration:

$$\text{Lambda engine out} = \lambda_{EO} = \frac{\left(\dfrac{mole\, O_{2\,EO}}{mole\, C_{EO}} \right)}{\left(\dfrac{mole\, O_2}{mole\, C} \right)_{stoich}} \qquad \text{(Eq. a)}$$

$$O_{2\,TLP} = O_{2\,EO} + O_{2\,released}$$

$$C_{TLP} = C_{EO} + C_{stored}$$

[0017] From oxygen and carbon balance relations:

$$C_{stored} = 2/3\, O_{2\,released}$$

$$\text{Lambda tailpipe} = \lambda_{TLP} = \frac{\left(\dfrac{mole\,O_{2\,TLP}}{mole\,C_{TLP}} \right)}{\left(\dfrac{mole\,O_2}{mole\,C} \right)_{stoich}} \qquad \text{(Eq. b)}$$

[0018] From Eq. a and Eq. b:

$$O_{2\,released} = O_{2\,EO} \cdot ((\lambda_{TLP} - \lambda_{EO})/\lambda_{EO})/(1 + 2/3(O_2/C)_{stoich} \cdot \lambda_{TLP}).dt$$

[0019] As 1 NO_2 release transfers 0.75 moles of oxygen to the gas, NO_2 release is related to lambda deviation as follows:

$$FNO_{2\,released} = \frac{4}{3} \cdot \int O_2 EO \left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1 \right) \left(\frac{1}{1 + \dfrac{2}{3}\left(\dfrac{mole\,O_2}{mole\,C} \right)_{stoich} \lambda_{TLP}} \right) dt$$

[0020] O_2 flow ($O_{2\,EO}$) can be replaced with

$$Airflow \cdot \left(\frac{mole\,O_2}{mole\,C} \right)_{air} :$$

$$FNO_{2\,released} = \frac{4}{3} \left(\frac{mole\,O_2}{mole\,air} \right)_{air} \cdot \int \left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1 \right) \left(\frac{1}{1 + \dfrac{2}{3}\left(\dfrac{mole\,O_2}{mole\,C} \right)_{stoich} \lambda_{TLP}} \right) Airflow_{rich\,pulse} \cdot dt$$

$$\text{(Eq. c)}$$

[0021] But this formula is not strictly applicable as such , because oxygen is also stored during lean phase on oxygen storing material (OSM) and later released during rich pulse. If lambda deviation was only due to O_2 release, the Fictive $O_{2\,release}$ ($FO_{2\,release}$) would be:

$$FO_2\,released = \left(\frac{mole\,O_2}{mole\,air} \right)_{air} \left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1 \right) Airflow_{rich\,pulse} \cdot dt \quad \text{(Eq. d)}$$

[0022] To differentiate actual NO_2 contribution from total release:

$$NO_2 \text{ contribution} = 1 - O_2 \text{ contribution} \qquad \text{(Eq. e)}$$

with

$$O_2 \text{ contribution} = O_{2\,released}/FO_{2\,released} \qquad\qquad \text{(Eq. f)}$$

wherein $FO_{2\,released} = Sum(O_{2released}\cdot dt)$ over the complete rich pulse To calculate Actual $NO_{2\,released}$:

$$ANO_{2\,released} = NO_2 \text{ contribution}/FNO_{2\,released} \qquad\qquad \text{(Eq. g)}$$

wherein $FNO_{2\,released} = Sum(NO_{2released}\cdot dt)$ over the complete rich pulse

[0023] The final equation is:

$$ANO_{2\,released} = [1 - (O_{2released}/FO_{2\,released})]\cdot(FNO_{2\,released}) \qquad\qquad \text{(Eq. h)}$$

[0024] A second aspect of the present invention is a system for monitoring the adsorptive capacity of a NO_x adsorber of an internal combustion engine, comprising:

- oxygen detection means upstream and/or downstream of the NO_x adsorber
- means to generate a command to switch the operation of the internal combustion engine from lean to rich and from rich to lean operating conditions
- means to perform the calculation of NO_x released during rich pulse using the output of the oxygen detection means in a release model based on lambda deviation across the adsorber and the release chemistry of NO_2 from said adsorber
- optional means to store successive calculation values, and
- means to use at least one of the calculation values to update an adaptative capacity model to determine the duration of the lean phase and/or of the rich pulse.

[0025] In practice, such a system used e.g. in an automobile, enables a close control of the performance of the NO_x adsorber without tedious calibration steps, while keeping the fuel consumption due to NO_x reduction as low as possible.

[0026] The oxygen detecting means that could be used are generally known in the art and comprise stoichometry sensors for detection of the stoichiometry (also called switching type oxygen sensors) or wide range sensors (such as UEGO Universal Exhaust Gas oxygen Sensor).

[0027] The means to generate a command, to perform the calculations, to optionally store any necessary values and to update the adaptive capacity model may be integrated in one dedicated logical unit or even be part of a larger unit of engine diagnostic and control.

[0028] In a preferred embodiment of the present invention, the system also controls sulfur poisoning of the adsorber and further comprises

- means to use at least one of the calculation values to update an adaptative capacity model to determine the necessity of a desulfation of the NO_x adsorber due to excessive sulfur poisoning, and
- means to generate a command to trigger a desulfation of the NO_x adsorber.

[0029] The model used by the present system may be based on the following equation:

$$ANO_{2\,released} = \left[1 - \frac{AO_{2\,released}}{FO_{2\,released}}\right]FNO_{2\,released}$$

with the above defined meanings.

[0030] A specific embodiment of the invention provides a system, wherein

- the oxygen detection means comprise an UEGO type oxygen sensor upstream and a switching type oxygen sensor downstream of the adsorber
- the release model is based on following equation:

$$ANO_2 \text{ released} = \frac{4}{3}\left[\frac{1}{1+\frac{2}{3}\left(\dfrac{mole\,O_2}{mole\,C}\right)_{stoich}}\right]\left[\left[\left(\frac{mole\,O_2}{mole\,air}\right)_{air}\int_{rich\,pulse}\left(\frac{1}{\lambda_{EO}}-1\right)Airflow_{rich\,pulse}\cdot dt\right]-AO_2\,release\right]$$

(Eq. i)

with the above defined meanings.

[0031] This equation is obtained by replacing the $FO_{2\,released}$ and $FNO_{2\,released}$ in Eq. h by Eq. c and Eq. d, respectively. In this particular case, lambda EO (λ_{EO}) is measured, whereas lambda TLP (λ_{TLP}) = 1. This assumption is valid if rich pulse is terminated before a significant rich drift at the tailpipe side occurs.

[0032] In a further specific embodiment, there is provided a system wherein

- the oxygen detection means comprise an UEGO type oxygen sensor downstream and a switching type oxygen sensor upstream of the adsorber
- the release model is based on following equation:

$$ANO_2 \text{ released} = \frac{4}{5}\cdot k\cdot\left[\left[\left(\frac{mole\,O_2}{mole\,air}\right)_{air}\int_{rich\,pulse}\left(\frac{1}{\lambda_{EO}}-1\right)Airflow_{rich\,pulse}\cdot dt\right]-AO_2\,release\right]$$

(Eq. j)

wherein:

$$k = \frac{\displaystyle\int_{rich\,pulse}\frac{\left(\dfrac{1}{\lambda_{EO}}-1\right)}{\left(1+\dfrac{2}{3}\cdot c\cdot\lambda_{TLP}\right)}\cdot Airflow_{rich\,pulse}\cdot dt}{\displaystyle\int_{rich\,pulse}\left(\dfrac{1}{\lambda_{EO}}-1\right)Airflow_{rich\,pulse}\cdot dt}$$

and

$$c:\quad \left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}$$

all other terms having the meanings defined above.

[0033] In this embodiment, injecting Eq. c and Eq. d in Eq. h, gives the following theoretical formula:

$$\frac{1}{2}ANO_{2\,released} = \frac{4}{5}\left[\left(\left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{r.p.}\frac{\left(\frac{1}{\lambda_{EO}}-1\right)}{\left(1+\frac{2}{3}.c\lambda_{TLP}\right)}.Airflow_{r.p.}.dt\right) - \left(\frac{\int_{r.p.}\frac{\left(\frac{1}{\lambda_{EO}}-1\right)}{\left(1+\frac{2}{3}.c\lambda_{TLP}\right)}.Airflow_{r.p.}.dt}{\int_{rich\,pulse}\left(\frac{1}{\lambda_{EO}}-1\right)Airflow_{r.p.}.dt}\right)ANO_{2\,released}\right]$$

(Eq. k)

[0034]   In practice, this theoretical formula may be simplified to Eq. j with the meanings given above for k and c.

Claims

1. Method of monitoring the adsorptive capacity of a NO_x adsorber of an internal combustion engine, comprising the following steps:

    1) identification of O_2 moles released from the adsorber during rich pulse regeneration,
    2) calculation of NO_2 moles released during rich pulse regeneration using the value from step 1 in a release model based on lambda deviation across the adsorber and the release chemistry of NO_2 from said adsorber
    3) optional storage of successive results of steps 1 and 2
    4) use of the results of step 2 and/or 3 to update an adaptative capacity model to control the duration of the lean phase and/or of the rich pulse.

2. Method as claimed in claim 1, comprising the following additional step:

    5) use of the results of step 2 and/or 3 to update an adaptative capacity model to detect sulfur poisoning of the adsorber and to trigger a desulfation process.

3. Method as claimed in any one of the preceding claims, wherein the release model in step 2 is based on following equation:

$$ANO_{2\,released} = \left[1 - \frac{AO_{2\,released}}{FO_{2\,released}}\right]FNO_{2\,released}$$

wherein :

$ANO_{2\,released}$:   actual (calculated) moles of NO_2 released from the adsorber during rich pulse regeneration
$AO_{2\,released}$:   measured O_2 moles during rich pulse

$$FO_{2\,released} = \left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{rich\,pulse}\left(\frac{\lambda_{TLP}}{\lambda_{EO}}-1\right)Airflow_{rich\,pulse}.dt$$

$$FNO_{2\,released} = \frac{4}{3}\left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{rich\,pulse}\left(\frac{\lambda_{TLP}}{\lambda_{EO}}-1\right)\left(\frac{1}{1+\frac{2}{3}\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}\lambda_{TLP}}\right)Airflow_{rich\,pulse}\,.dt$$

$$\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich} :$$

oxygen to carbon ratio at stoichiometric operating conditions

$$\left(\frac{mole\,O_2}{mole\,air}\right)_{air} :$$

molar oxygen to air ratio in ambient air

$$\lambda_{EO} = \frac{\left(\frac{mole\,O_{2EO}}{mole\,C_{EO}}\right)}{\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}} :$$

lambda value upstream of the adsorber (EO, engine out)

$$\lambda_{TLP} = \frac{\left(\frac{mole\,O_{2TLP}}{mole\,C_{TLP}}\right)}{\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}} :$$

lambda value downstream of the adsorber (TLP, tailpipe)

$Airflow_{rich\,pulse}$: airflow during rich pulse.

4. System for monitoring the adsorptive capacity of a NO_x adsorber of an internal combustion engine, comprising:

   - oxygen detection means upstream and/or downstream of the NO_x adsorber
   - means to generate a command to switch the operation of the internal combustion engine from lean to rich and from rich to lean operating conditions
   - means to perform the calculation of NO_x released during rich pulse using the output of the oxygen detection means in a release model based on lambda deviation across the adsorber and the release chemistry of NO_2 from said adsorber
   - optional means to store successive calculation values, and
   - means to use at least one of the calculation values to update an adaptative capacity model to determine the duration of the lean phase and/or of the rich pulse.

5. System as claimed in claim 4, further comprising:

- means to use at least one of the calculation values to update an adaptative capacity model to determine the necessity of a desulfation of the NO_x adsorber due to excessive sulfur poisoning, and
- means to generate a command to trigger a desulfation of the NO_x adsorber.

6. System as claimed in any one of claims 4 or 5, wherein the release model is based on following equation:

$$ANO_{2\,released} = \left[1 - \frac{AO_{2\,released}}{FO_{2\,released}}\right] FNO_{2\,released}$$

wherein:

$ANO_{2\,released}$: actual (calculated) moles of NO_2 released from the adsorber during rich pulse regeneration

$AO_{2\,released}$: measured O_2 moles during rich pulse

$$FO_{2\,released} = \left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{rich\,pulse} \left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1\right) Airflow_{rich\,pulse} \cdot dt$$

$$FNO_{2\,released} = \frac{4}{3}\left(\frac{mole\,O_2}{mole\,air}\right)_{air} \cdot \int_{rich\,pulse} \left(\frac{\lambda_{TLP}}{\lambda_{EO}} - 1\right) \left(\frac{1}{1 + \frac{2}{3}\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich} \lambda_{TLP}}\right) Airflow_{rich\,pulse} \cdot dt$$

$$\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich} :$$

oxygen to carbon ratio at stoichiometric operating conditions

$$\left(\frac{mole\,O_2}{mole\,air}\right)_{air} :$$

molar oxygen to air ratio in ambient air

$$\lambda_{EO} = \frac{\left(\frac{mole\,O_{2\,EO}}{mole\,C_{EO}}\right)}{\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich}} :$$

lambda value upstream of the adsorber (EO, engine out)

$$\lambda_{TLP} = \frac{\left(\dfrac{mole\,O_{2TLP}}{mole\,C_{TLP}}\right)}{\left(\dfrac{mole\,O_2}{mole\,C}\right)_{stoich}} :$$

lambda value downstream of the adsorber (TLP, tailpipe)

Airflow$_{rich\,pulse}$:   airflow during rich pulse.

7. System as claimed in claim 6, wherein

- the oxygen detection means comprise an UEGO type oxygen sensor upstream and a switching type oxygen sensor downstream of the adsorber
- the release model is based on following equation:

$$ANO_2\ released = \frac{4}{3}\left[\frac{1}{1+\frac{2}{3}\left(\dfrac{mole\,O_2}{mole\,C}\right)_{stoich}}\right]\left[\left[\left(\frac{mole\,O_2}{mole\,air}\right)_{air}\int_{rich\,pulse}\left(\frac{1}{\lambda_{EO}}-1\right)Airflow_{rich\,pulse}.dt\right]-AO_2\ release\right]$$

wherein :

ANO$_2$ released :   actual (calculated) moles of NO$_2$ released from the adsorber during rich pulse regeneration

$$\left(\frac{mole\,O_2}{mole\,C}\right)_{stoich} :$$

oxygen to carbon ratio at stoichiometric operating conditions

$$\left(\frac{mole\,O_2}{mole\,air}\right)_{air} :$$

molar oxygen to air ratio in ambient air

$$\lambda_{EO} = \frac{\left(\dfrac{mole\,O_{2EO}}{mole\,C_{EO}}\right)}{\left(\dfrac{mole\,O_2}{mole\,C}\right)_{stoich}} :$$

lambda value upstream of the adsorber (EO, engine out)
Airflow$_{rich\,pulse}$:   airflow during rich pulse
AO$_2$ released :   measured O$_2$ moles during rich pulse.

8. System as claimed in claim 6, wherein

- the oxygen detection means comprise an UEGO type oxygen sensor downstream and a switching type oxygen sensor upstream of the adsorber

- the release model is based on following equation:

$$ANO_2 \; released = \frac{4}{5} k. \left[\left[\left(\frac{mole\,O_2}{mole\,air} \right)_{air} \int_{rich\,pulse} \left(\frac{1}{\lambda_{EO}} - 1 \right) Airflow_{rich\,pulse}.dt \right] - AO_2 \; release \right]$$

wherein :

ANO_2 released :   actual (calculated) moles of NO_2 released from the adsorber during rich pulse regeneration

$$k = \frac{\displaystyle\int_{rich\,pulse} \frac{\left(\dfrac{1}{\lambda_{EO}} - 1 \right)}{\left(1 + \dfrac{2}{3}.c.\lambda_{TLP} \right)} . Airflow_{rich\,pulse}.dt}{\displaystyle\int_{rich\,pulse} \left(\dfrac{1}{\lambda_{EO}} - 1 \right) Airflow_{rich\,pulse}.dt}$$

c : constant

$$\left(\frac{mole\,O_2}{mole\,C} \right)_{stoich} :$$

oxygen to carbon ratio at stoichiometric operating conditions

$$\left(\frac{mole\,O_2}{mole\,air} \right)_{air} :$$

molar oxygen to air ratio in ambient air

$$\lambda_{EO} = \frac{\left(\dfrac{mole\,O_{2EO}}{mole\,C_{EO}} \right)}{\left(\dfrac{mole\,O_2}{mole\,C} \right)_{stoich}} :$$

lambda value upstream of the adsorber (EO, engine out)

$$\lambda_{TLP} = \frac{\left(\dfrac{mole\,O_{2TLP}}{mole\,C_{TLP}} \right)}{\left(\dfrac{mole\,O_2}{mole\,C} \right)_{stoich}} :$$

lambda value downstream of the adsorber (TLP, tailpipe)

$Airflow_{rich\ pulse}$: airflow during rich pulse

$AO_2\ released$: measured O_2 moles during rich pulse.

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 02 01 2811

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 October 2002	Faria, C

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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